Underground Facility Infrastructure

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Snowmass Community Study
Tuesday July 30, 2013

Deep Science Cover Page

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In a Post-DUSEL World

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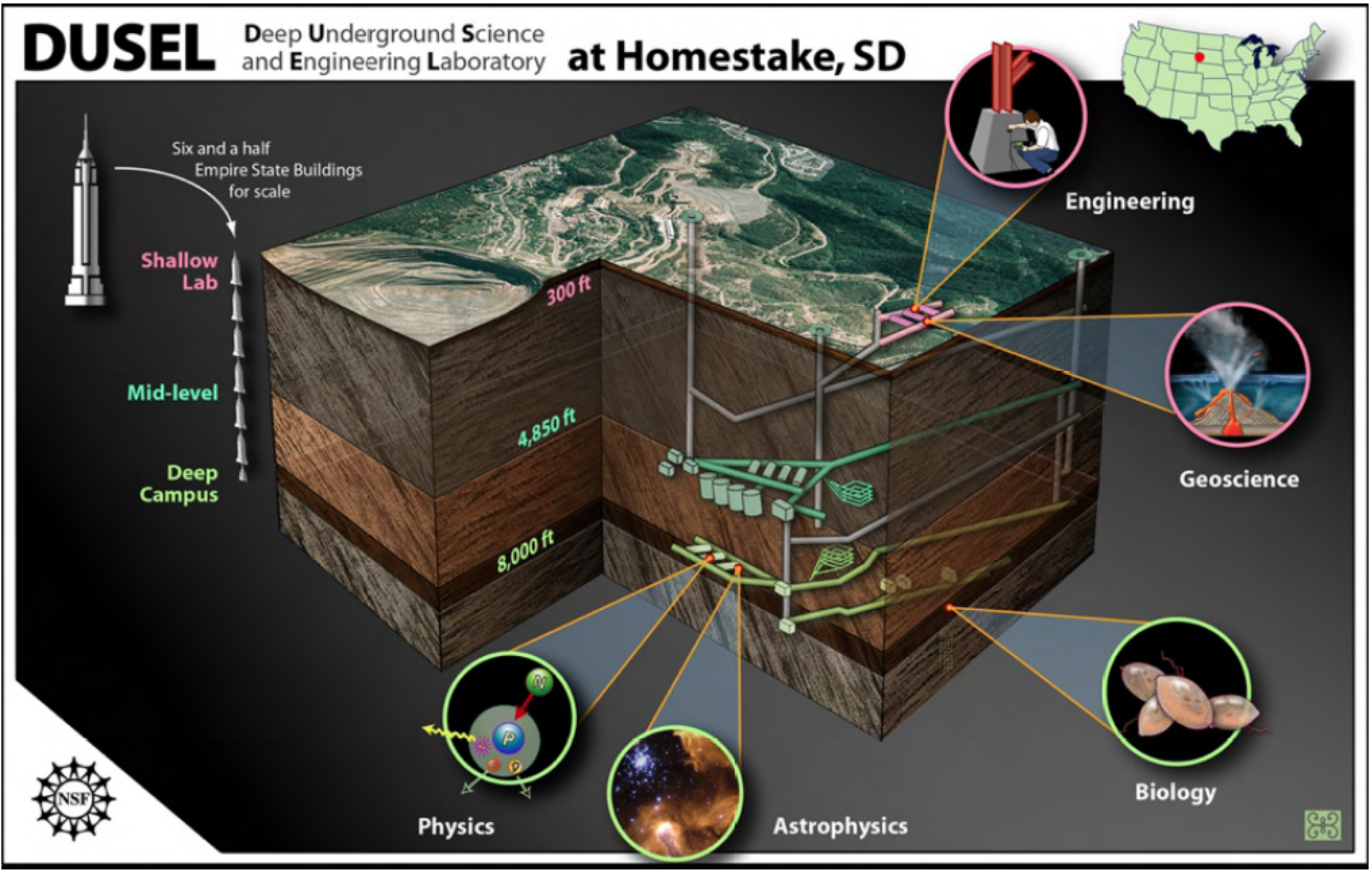
Model 1. One National Lab with deep and intermediate space, infrastructure and interdisciplinary studies



Examples of Model 1

LNGS, Gran Sasso, Italy **SNOLAB, Sudbury, Canada** **Kamioka Observatory, Japan**

Both built up over time, starting with a flagship experiment.
Infrastructure followed. Now they take advantage of economy of scale
and continued investment by the host country
and development of a user community beyond Physics

Model 2: Dedicated labs for one experiment, with some infrastructure, depends on use for others at remote locations.

In Europe, successfully leveraged by umbrella organizations such as
ILIAS "Integrated Large Scale Infrastructure for Astroparticle Science"
EULABS - Collaboration agreement linking European labs for closer coordination and signed by the agencies that run the various labs.

Can we also
* Exploit economy of scale where we can: SURF and SNOLAB (Model 1)
* Exploit the space and strengths of smaller US labs by creating collaborative entities

?

MEMORANDUM OF UNDERSTANDING FOR THE ESTABLISHMENT OF THE COORDINATION NETWORK OF EUROPEAN UNDERGROUND LABORATORIES « EULABS » (2011)

Signed by CEA, CNRS, INFN and LSC
for underground laboratories LNGS, LSC and LSM.

The Parties have agreed as follows:

Article 1 - Purpose

The purpose of this Memorandum of Understanding is the establishment of a European network named "European Underground Laboratories – EuLabs", the

purpose of which is to play a coordination role and to exchange information concerning the *"Underground Science and Technology"*, hereinafter referred to as the Network Theme.

The topics included in the Network Theme are more specifically identified as follows:

- Low-background technologies
- Scientific and technical data-bases
- Data-base of publications
- Exchange of researchers and personnel
- Quality standards and benchmarking for underground infrastructures
- Exchange of information on the scientific advisory procedures
- Environmental policies
- Safety regulations
- Outreach activities
- Development of a common website for the visibility of the underground science and technology
- Relationships with non-EU underground laboratories

Any other topic may be added on an occasional basis after discussion and unanimous agreement of all members of the Network Committee as described in Article 3 below.

The permanent inclusion of a new topic in the Network Theme shall be unanimously agreed upon by the Parties.

The Network is composed of the Laboratories. The Network composition may change according to the rules set in Articles 5 and 6 below.

2

What Infrastructure requires an Underground Facility?

Production screening (high throughput) for shielding and detectors: *More, More, MORE*

ASSAY

Increased sensitivity screeners to identify

GeMPI style gamma spectroscopy (ultralow background shielding and crystals)

R&D on new types of screeners (e.g. beta cage, XIA alpha counter, immersion....)

Access to ICPMS, AMS, and new high-precision techniques

Production/storage of radiopure materials

Copper electroforming, Purification plants (noble liquids, water, LS), crystal growing

Stockpiling of materials to avoid cosmogenic activation

Radon reduction, plate-out studies

Prototyping new experiments: How do you stage a new experiment?

R&D

1. Prove the technique works (in a convenient lab)
2. Make it "low background"
   a. decide on materials (requires use of screening detectors)
   b. run it underground and get a physics results as well as proof of principle
3. Discover unexpected background sources (run underground)
4. Scale up and run for a long time (deeper underground)

Develop new active veto strategies for α-n, SF neutrons: *Neutron vetos/monitors*

Benchmarking Geant4/FLUKA: *Compare to data on n's, underground cosmogenic showers*

Goal of the Snowmass NAF2 Underground Infrastructure Group

- **Identify the assay needs of all dark matter (and $0\nu\beta\beta$, astrophysics, proton decay)**

  CF1 (Direct WIMP Detection) is compiling the results of their survey

  wiki: http://www.snowmass2013.org/tiki-index.php?page=materials+details

- **Identify the existing labs in the US and Abroad which can supply common infrastructure**

  wiki: http://zzz.physics.umn.edu/lowrad/consortium#available_assay_technology

  Plus higher level summary tables

What currently exists and how much is available to outside users.

Table 1. US Assay Resources [2]

Facility	Depth (mwe)	Suite of detectors and technology
Berkeley LBCF	surface	2 HPGe (1 with muon veto) managed by LBNL 100% use for others NaI, BF_3 counting, Shielded R&D space
PNNL	surface	ICPMS: Dedicated instrument and clean room facilities for low bkgd assay 6 commercially shielded HPGe detectors considering use for others
PNNL ULab	30	Copper Electroforming and clean machining 14-crystal HPGe array, considering use for others Multiple commercial HPGe for various stakeholders
Oroville (LBNL)	530	1 HPGe managed by LBNL, 100% use for others Large Shielded R&D space
Kimballton (KURF)	1450	2 HPGe managed by UNC/TUNL. 50% use by others
Soudan	2100	1 HPGe managed by CDMS, 10% use by others. 1 HPGe managed by Brown, dedicated to LUX/LZ 6000 m^3 lab lined with muon tracker + 2 muon-correlated neutron detectors Large R&D space with muon tag provided
Homestake (SURF)	4300	1 HPGe managed by CUBED, priority to LZ, Majorana, other users by negotiation.

Facility	Depth (mwe)	Suite of detectors and technology
Japan	Surface	1 HPGe (with active veto) managed by KamLAND, currently 100%, but may consider use for others. 1 HePG managed by CANDLES in Osaka (sea level), currently 90%, with 10% use for others.
Kamioka Observatory, Japan	2700	Each experimental group has their own devices for screening and assay, but will consider use by others. 1 HPGe managed by KamLAND, currently 100% 1 HPGe under construction by KamLAND: 100% 1 HPGe under construction by CANDLES: 100% 3 HPGe (2 p-type, 1 n-type)100% SuperK and XMASS Underground ICP-MS and API-MS managed by SuperK and XMASS (100%). Many radon detectors to measure radon emanation of materials, managed by SuperK and XMASS (100%)
CanFranc (LSC) Spain	2450	5 HPGe p-type 100% usage by LSC. Outside collaboration possible 2 HPGe p-type to be installed by end of summer 2013
STELLA at LNGS Gran Sasso Italy	3800	10 HPGe operated by INFN as a user facility 1 HPGe with 100% usage by XENON and GERDA, (DARWIN in future), Radon mitigation underway
LSM (Modane) France	4800	15 HPGe with 6 dedicated to material selection. - 2 detectors, 100% usage by SuperNEMO - 1 detector 100% usage by EDELWEISS - 3 detectors 100% dedicated to Modane exp experiments installed in Modane 2 detectors may be available to others at level of 5-10%
SNOLAB Canada	6010	1 PGT coax HPGe 54% usage by Canadian based experiments, 34% usage by US based experiments, 12% usage by SNOLAB 1 Canberra well HPGe , 100% by SNO+ and DEAP 11 Electrostatic Counters (alpha counters), 100% usage by EXO, in future SNO+, PICASSO and MiniCLEAN 8 Alpha-Beta counters, 100% usage by SNO+ available for other experiments on request 1 Canberra coax HPGe (currently being refurbished) The SNOLAB facilities are used by SNOLAB based experiments, but can be negotiated during down time
CJPL (JinPing) China	6800	1 HPGe managed by PandaX, 100% for PandaX 1 HPGe managed by CDEX, 90% usage by CDEX 2 HPGe to be installed by end of 2013: ~ 70% CDEX, ~30% availability reserved for others.

What currently exists and how much is available to outside users.

Table 2.
International Assay Capabilities

…not yet complete

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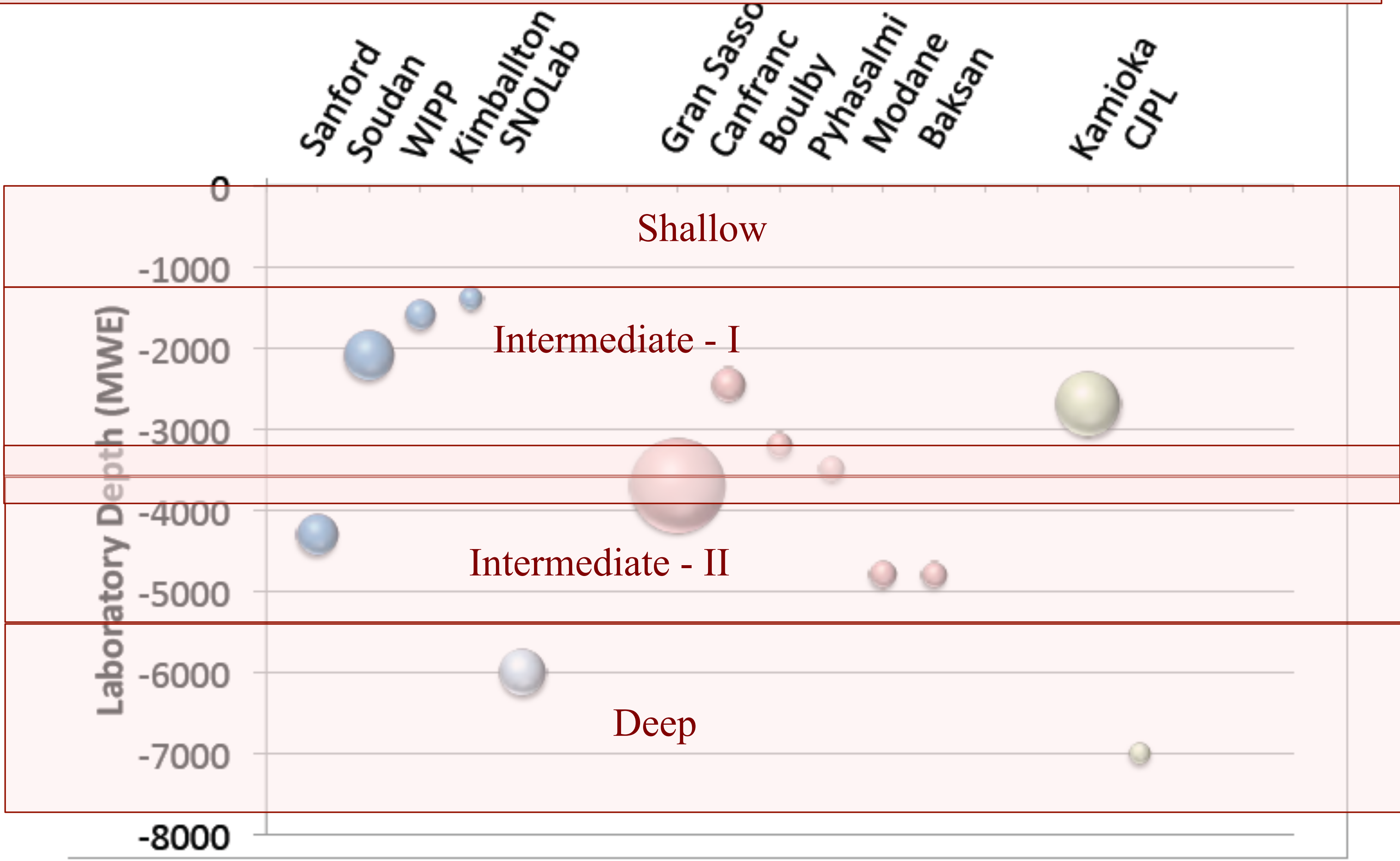
- **Quantify the gap between what we need and what we have.**

- **Suggest a means to address this shortfall.**
  Organization of what exists and sharing of resources/information
  Invest in more assay capability at current sensitivity
  Push the frontier of sensitivity (R&D)
  Open up high sensitivity assay to the community

- **Do we have equipped US underground lab space enough for new investments?**
  YES – if we efficiently use the existing suite of underground laboratories.

What is the right depth for Common Infrastructure?



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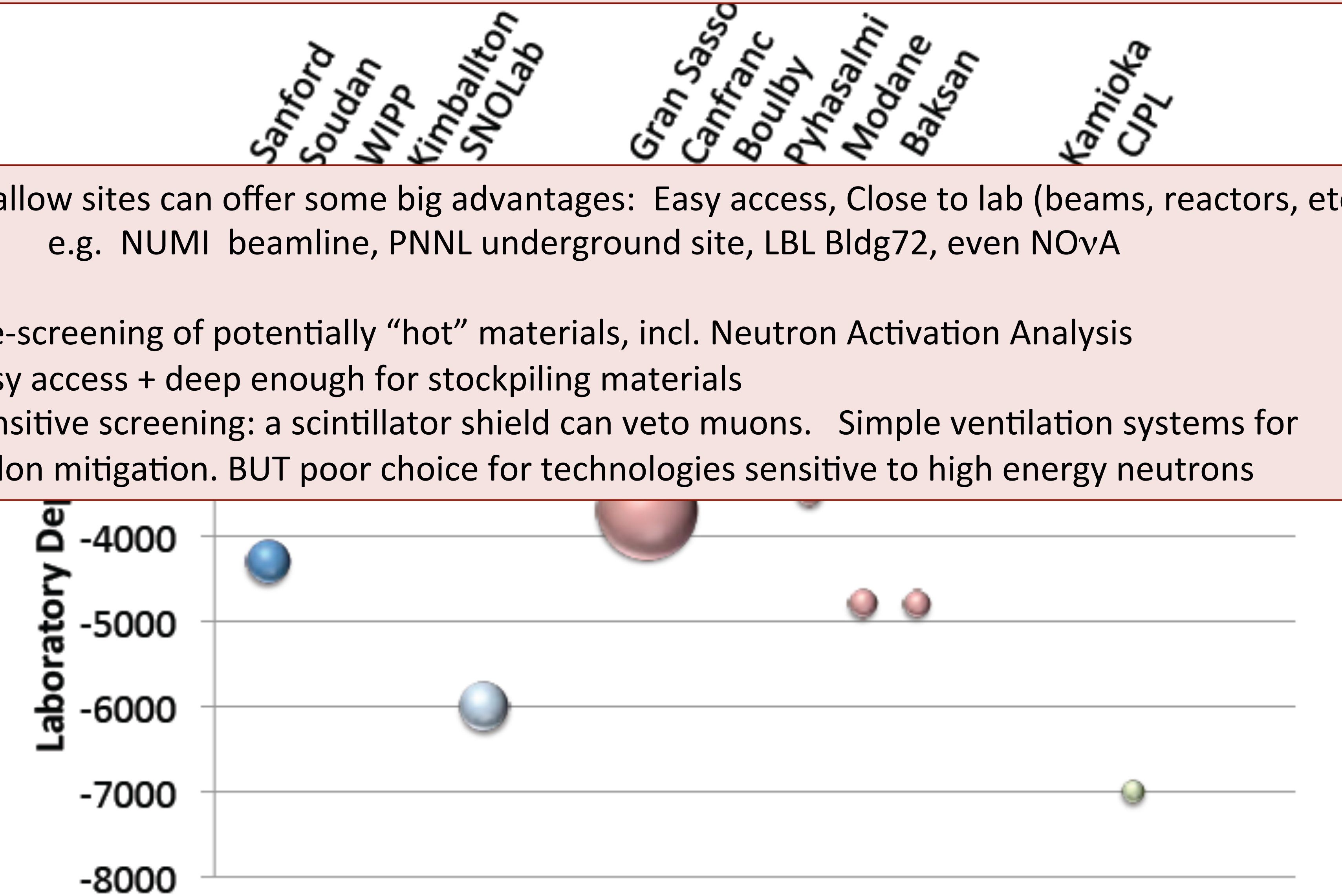
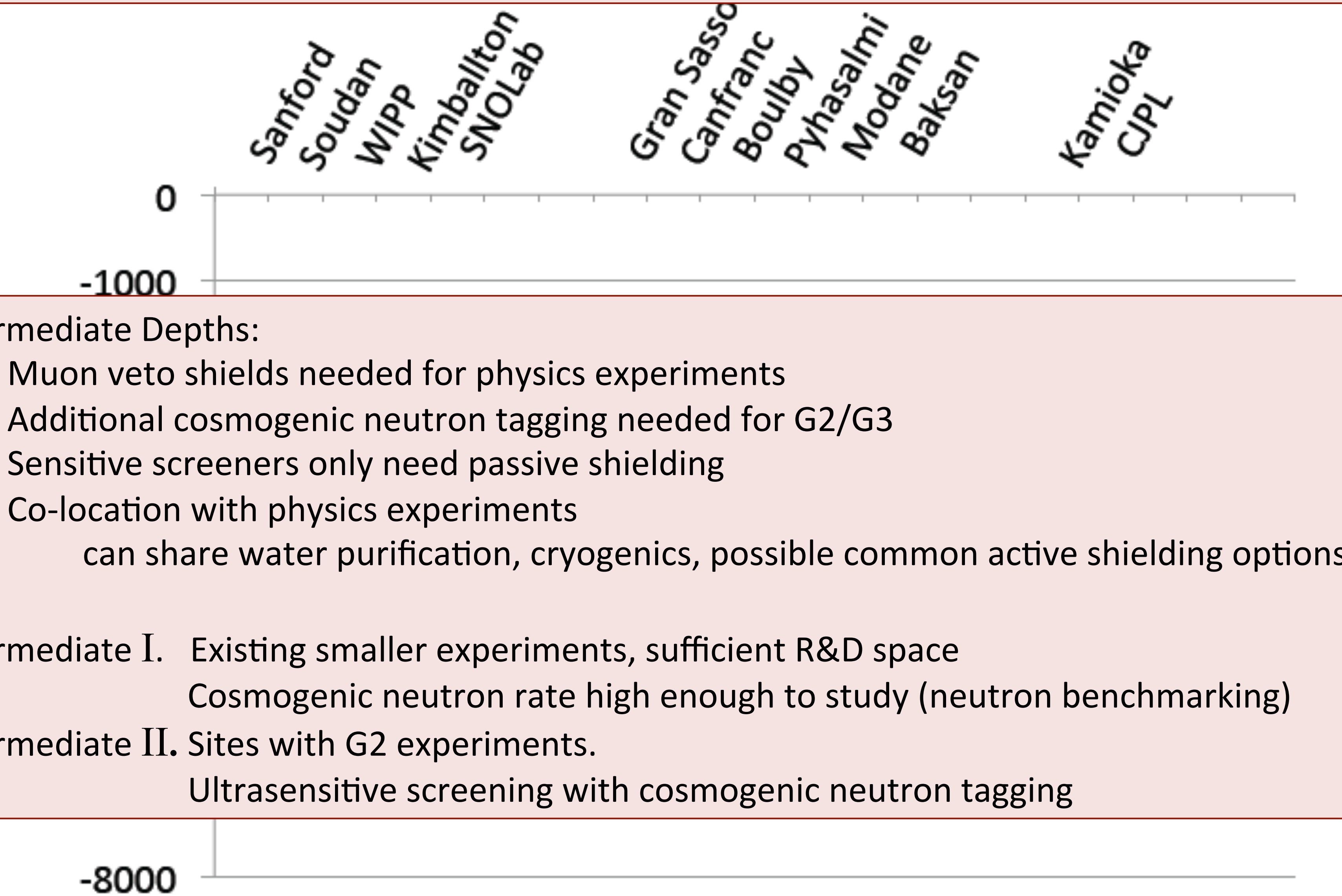


Shallow sites can offer some big advantages: Easy access, Close to lab (beams, reactors, etc)
e.g. NUMI beamline, PNNL underground site, LBL Bldg72, even NOνA

Pre-screening of potentially "hot" materials, incl. Neutron Activation Analysis
Easy access + deep enough for stockpiling materials
Sensitive screening: a scintillator shield can veto muons. Simple ventilation systems for radon mitigation. BUT poor choice for technologies sensitive to high energy neutrons

What is the right depth for Common Infrastructure?



Intermediate Depths:

Muon veto shields needed for physics experiments

Additional cosmogenic neutron tagging needed for G2/G3

Sensitive screeners only need passive shielding

Co-location with physics experiments

can share water purification, cryogenics, possible common active shielding options

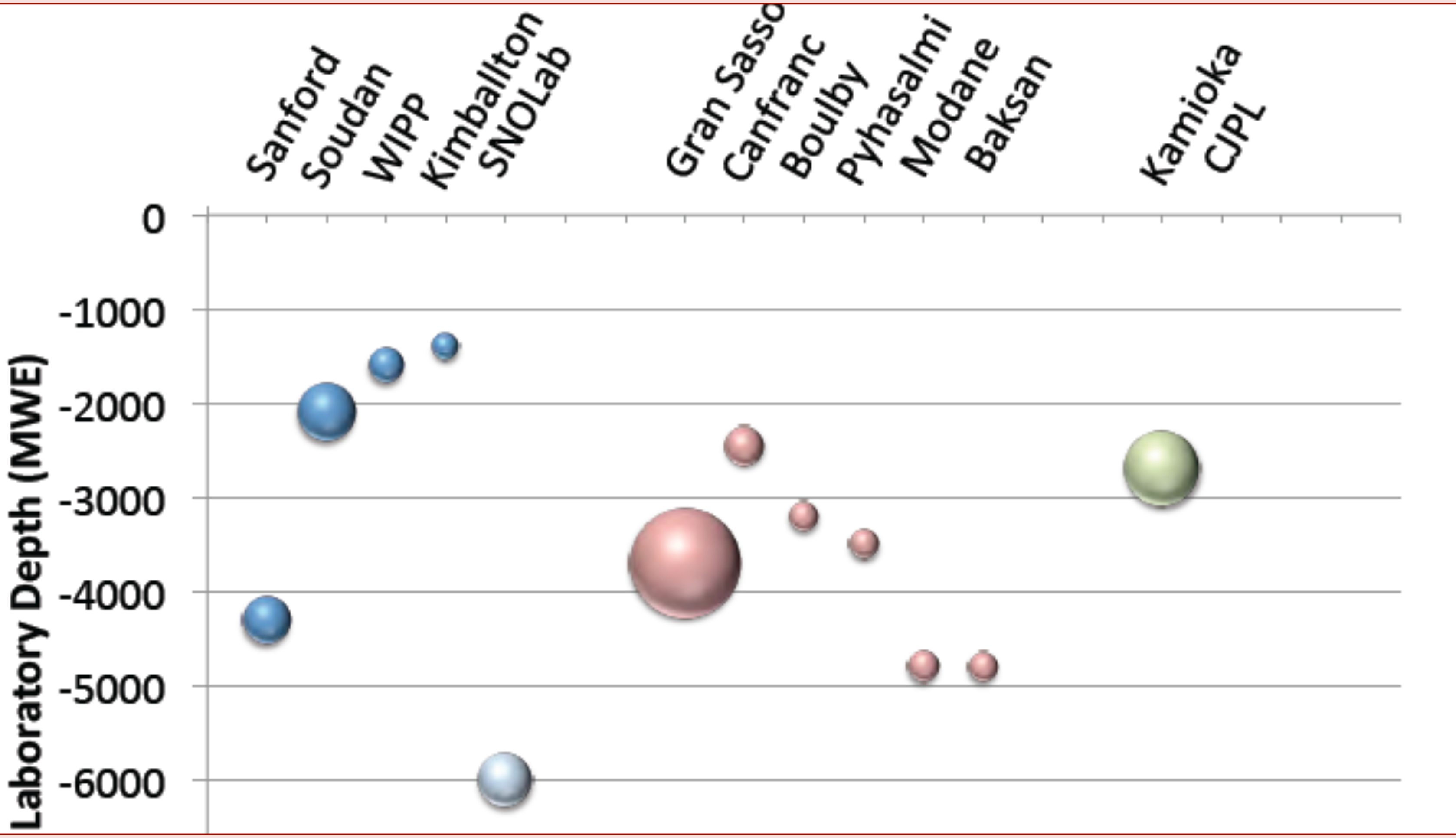
Intermediate I. Existing smaller experiments, sufficient R&D space

Cosmogenic neutron rate high enough to study (neutron benchmarking)

Intermediate II. Sites with G2 experiments.

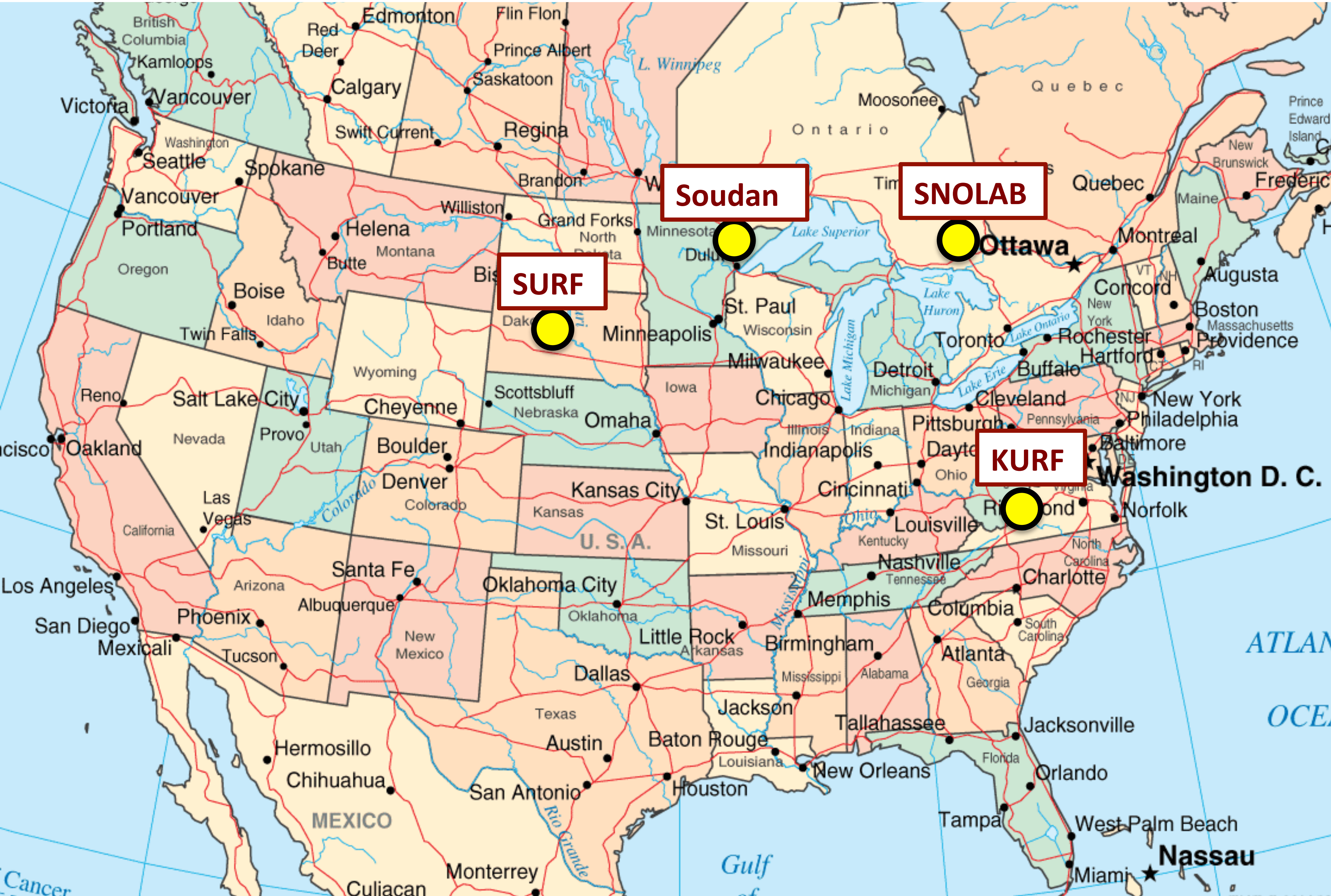
Ultrasensitive screening with cosmogenic neutron tagging

What is the right depth for Common Infrastructure?



Deepest sites: No cosmogenic tagging needed for G2/G3➔ Risk is mitigated down to ν-floor. Neutrons from α-n and SF in the shielding and detector materials becomes dominant bkgd. Active shielding against radiogenic neutrons will require large active shields similar to cosmogenic neutron tagging. Ultra-sensitive, immersion screeners are best here.

Underground Sites for Low Background Counting



Underground Screening Facilities have complementary strengths

SNOLAB 6010 m.w.e.

Deepest site and most developed infrastructure.
Current cooperation at the level of AARM (e.g. Universal Database)
Shared technology transfer worldwide (LRT, AARM)
Future resource sharing can be developed via MOU.
Funding sources can remain separate.

SURF 4300 m.w.e.

Shares location with users: LUX and Majorana Demonstrator
On-site staff
Cryogens, LUX shield, Purification plant, Cu electroforming

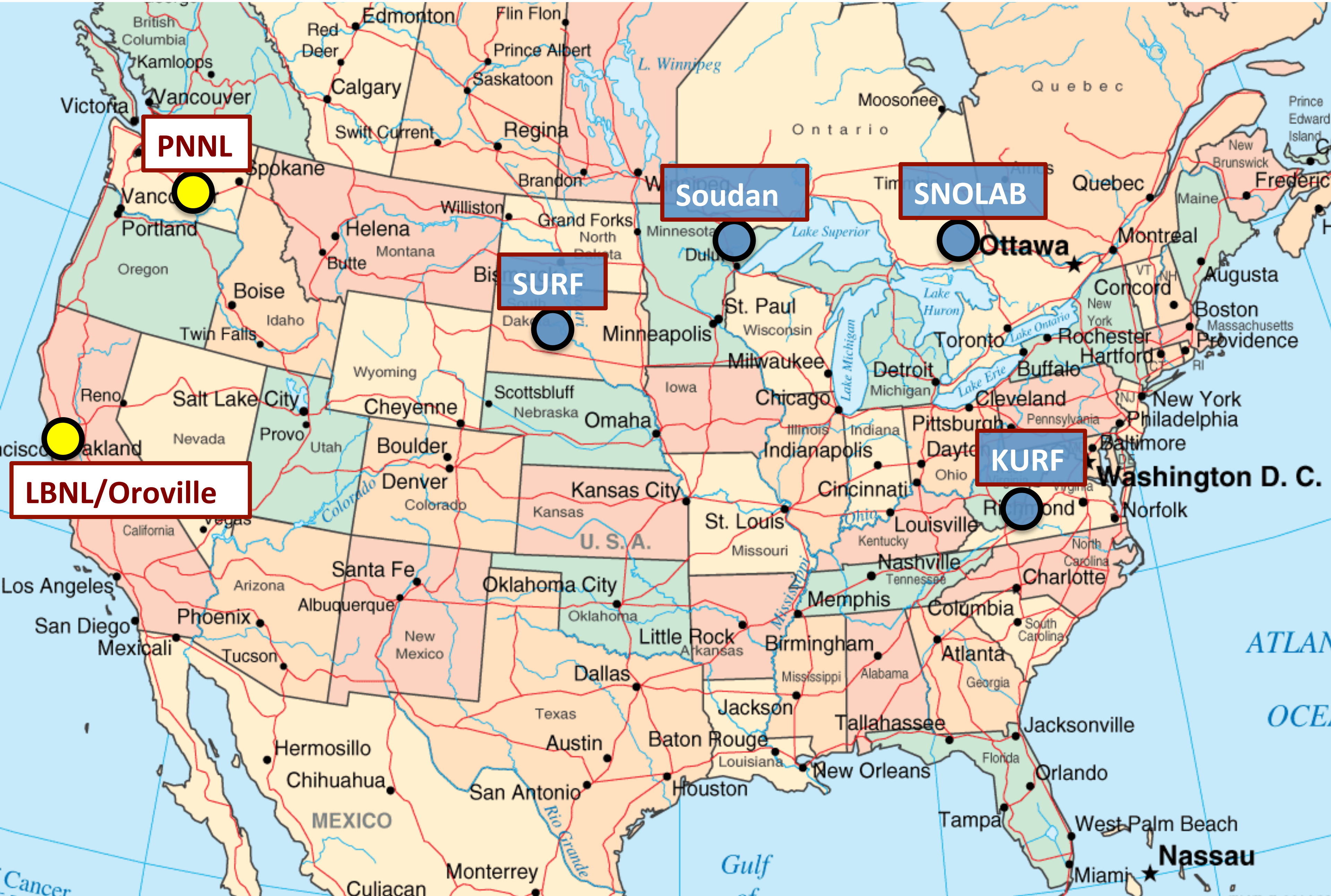
Soudan Underground Lab 2100 m.w.e.

Shares location with user: SuperCDMS, CoGeNT, remote user: LUX
On-site staff
Muon-shielded room and cosmogenic neutron studies, neutrino beam

KURF 1450 m.w.e.

Operate 2 HPGe for Majorana Demonstrator
Trained users/students close by.
Drive-in facility, low radon, easy access to multiple depths, fast neutron studies

Shallow Underground Sites for Low Background Counting



Shallow sites provide vital infrastructure without co-location
Lots of experience in providing use for others

PNNL Underground lab (30 mwe)

Traditionally interdisciplinary, use for others can be arranged
Electroforming high purity Cu (Installing SURF electroforming baths)
Ultra-low-bkgd proportional counters for Rn emanation, tritium, ^{37}Ar measurements
HPGe with muon veto, both single and arrays

LBNL Low Background Facilities

Long history as a user facility.
On-site staff

Surface Site at LBNL in a cave constructed of low-activity concrete

- 115% n-type HPGe with muon veto, HPGe (p-type), BF3, NAI
- space for R&D hosting.

Oroville (600 mwe)

- HPGe (85% p-type)
- large existing shielding for R&D hosting or new HPGe's

Counting isn't the whole story.

Surface analysis:

Probe elemental composition, sub-micron position and depth profiles.. using ion or electron beams, X-rays, etc: RBS, XRF, FReS, NRA, Auger, PIXE …

Available in many institutions, but in-house capability provides fast turn-around and expertise

Mass Spectroscopy: *ICPMS, GDMS, TIMS, SIMS, AMS*

Extract and accelerate charged ions from a sample and measure the trajectory corresponding to the correct charge-to-mass ratio for the element in question.

Quoted sensitivity depends on magnetic spectrometer and sample dispersion technique

Real sensitivity depends on details of the sample prep and chemistry

Range of materials depends on R&D in digestion and dissolution techniques.

Neutron Activation Analysis

Induce neutron capture on sample and detect (via HPGe) γ-rays from de-excitation

Either prompt (usually in-situ) or delayed (ship to site).

Requires reactor > 10^{13} n cm^{-2} s^{-1} (or DT plasma generator)

Technique limited by the nuclear properties of trace element (~60% of elements activate)
and substrate (activation of substrate masks lines)

> ICPMS and NAA have proven their worth for HEP
> Experienced Personnel (and maintaining that expertise beyond projects) is VITAL.

A PROPOSAL in Process
HEP Infrastructure Funding for Centers of Excellence
in Assay and Related technologies

Assay

HPGe, ICPMS, NAA, atom trap
α,β counting, Rn emanation, etc.

Different Depths
Required for different modalities

Related technologies

Irradiation facilities for NAA,
Radiochemistry for ICPMS

Location & People matter
e.g. Near to reactors,
University partners with expertise

Process

- Capture the existing capability of each Assay Center (shallow and deep)
- Establish centers of specific expertise – make each a UNIQUE Facility
- Find a mechanism to integrate these under an umbrella funding and organizational entity

Build on the collaborative work already done by

LRT (Low Radiation Techniques – Biennial International Workshop)
AARM (Assay and Acquisition of Radiopure Materials – DUSEL S4 funding)
Integrative Tools for Underground Science – NSF May 2012 Solicitation

Initial Suite of Assay Centers of Excellence

ICP-MS and electro-refinement and actinide chemistry
PNNL

Gamma Counting
LBNL LBCF, SURF/CUBED, Soudan LBCF, KURF LBCF, PNNL UL

Neutron Activation Analysis
Reactor + surface HPGe: University partners (e.g. Alabama, UC Davis, Washington State University)

Add surface alpha, RN emanation, beta counting as we identify a need.
Then add another center or add to capabilities at one of the existing centers.

Fund as DOE-SC User Facilities with budgets to cover measurements and analyses as well as facility maintenance and upgrade. R&D costs as needed (via new proposal from the Consortium) to establish capabilities needed for G2 experiments.

Think of it as transitioning existing facilities into User Facilities to retain capabilities

Large Scale QA/QC campaigns will require their own additional project funding.

Managed by a board formed from the larger community. Grant renewed on a 3-yr cycle
Internal and Independent review processes established. Program Advisory Panel.

Synergies specific to low background counting/assay are very extensive

- Archaeology
- Anthropology
- Forensics
- Limnology
- Pollution control
- Epidemiology
- Hydrology
- Climate change
- Treaty verification
- Microbiology (tracers = movement and evolution)

And many more!

Can we exploit this? Would our creation of a network of sensitive screeners underground result in a new (paying) user community?

This has been successfully accomplished in Europe once integrative structures have been put in place.

Revisit DUSEL inter-disciplinary studies

For example:

FUNDAMENTAL AND APPLIED INTERDISCIPLINARY RESEARCH ORGANISATION

LSBB: Laboratoire Souterrain a Bas Bruit

University of Nice, University of Avignon, CNRS, Aix-Marseille University, OCA

RESOURCES

Karst underground water
Carbonate platform

- 4D properties of rocks (seismic, radar, noise, …)
- Dynamic of transfers in the deep unsaturated area of karst

INTERACTIONS FLUIDS & MEDIUM

Thermo-hydro-mechanical & poro-elastic processes , geomechanics

- Dynamic of fractured media (petrophysics within horizontal drifts and wells …)
- Geomechanics & induced seismicity
- CO_2 storage / Environment monitoring

WAVE PROPAGATION & RADIATIVE ENVIRONMENT

Seismology, Magnetism
Gamma / Neutrons / Muons
WIMPs

- Seismic hazard
- Electronic *vs* cosmic radiation hazard
- Water and rock density monitoring
- Sismo-Hydro-Magnetic couplings
- Dark matter

HIGH SENSITIVITY METROLOGY & MEASURES

Interferometry,
Densitometry,
Magnetometry,
Seismometry
Cold atom gravimetry, …

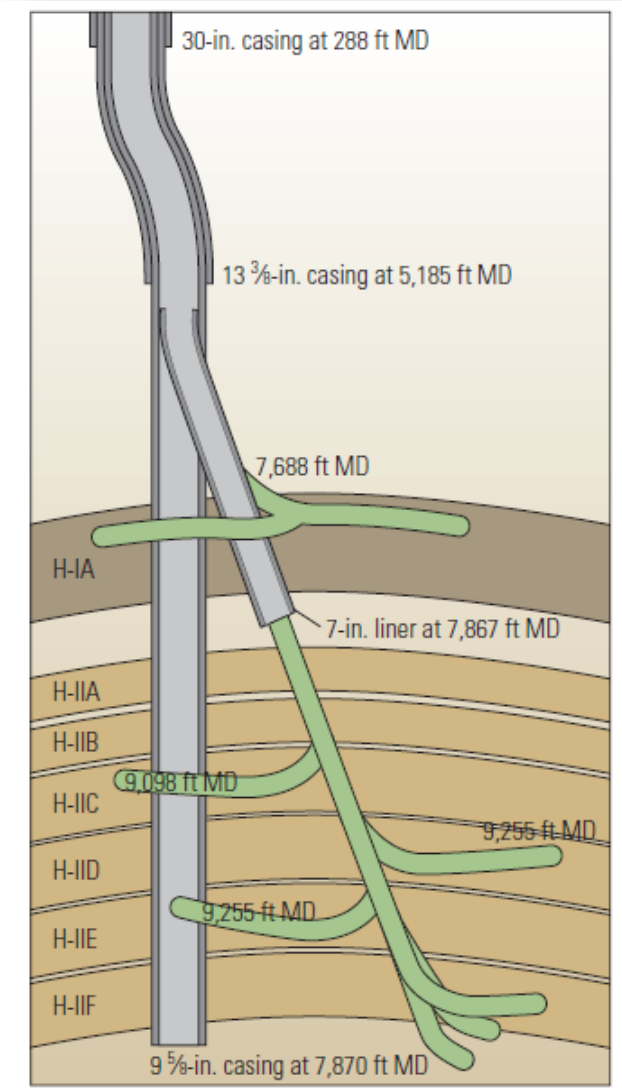
- Facility for tests & comparisons
- Applied research
- Technological demonstrators

Muon Tomography

Boulby Mine test by observing tides 3m/50m

<u>Other projects using Muon Tomography</u>

Imaging a magma chamber in a volcano
i.e. monitoring vocanic stability
Imaging hidden chambers in pyramids
Detecting nuclear contraband
CO_2 Sequestration
Monitoring of aquifer resources
Mineral and gas exploration



Underground Infrastructure Conclusions

Underground space should be reserved for **materials assay and storage**

- Selection of radiopure materials for shielding and detectors is a common need.
- The majority of such tests must be done underground, requiring sensitive detectors, expert personnel, and longterm storage of materials (e.g. Cu) sensitive to cosmogenic activation.
- Surveys of experimental needs worldwide far outstrip current assay capability.
- Operation as a user facility across multiple sites with existing expertise is the most efficient use of resources and personnel, and promotes prompt and open dissemination of results.

Underground space should be reserved for **small protoype testing and generic R&D**

- New technologies need to go underground to validate background performance
- Investment in common use elements (shielding, muon veto, croygenics, radon mitigation) in a reconfigurable user space supports generic R&D and high-risk/high-reward ideas.

There is enough infrastructure space for the future if existing US underground labs are included in the mix. Substantial past agency investment and future leverage of state and university funds make it cost effective and attractive to local users to maintain these sites for smaller experiments, generic R&D, and as elements of a centrally managed materials assay consortium.